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# White Spruce Regeneration Options on River Floodplains in the Yukon Territory

A.C. Gardner

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# WHITE SPRUCE REGENERATION OPTIONS ON RIVER FLOODPLAINS IN THE YUKON TERRITORY

By:

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## ABSTRACT

White spruce regeneration options tested on river floodplains of the Yukon Territory, including natural seeding, spot and broadcast seeding and planting on scarified and unscarified ground, were replicated for two years on two sites. Five years after establishment the results indicate that scarification increases seedling survival and growth, that broadcast seeding outperformed spot and natural seeding and that spring planting of container stock is a reliable regeneration technique. The infeasibility of plantation reforestation in the Yukon at present suggests a need for development and refinement of seeding techniques.



## RESUME

Dans deux stations inondables du Yukon, on a répété deux années de suite diverses techniques de régénération de l'épinette blanche, y compris la dispersion naturelle des graines, l'ensemencement sur placeaux et en plein ainsi que la plantation sur sol scarifié et non scarifié. Cinq ans après l'implantation, les résultats montrent que la scarification augmente la croissance et la survie des semis, que l'ensemencement en plein surpasse l'ensemencement sur placeaux et la dispersion naturelle des graines et que la plantation printanière de matériel en récipients est une technique fiable de régénération. En raison de l'impossibilité actuelle de reconstituer la forêt par plantation au Yukon, la mise au point et l'amélioration des techniques d'ensemencement sont indiquées.



## ACKNOWLEDGEMENT

The author is indebted to the Yukon Lands and Forests Service (YLFS) for the contributions of funding and field crew assistance in the establishment, maintenance and assessment of these trials. Particular thanks are extended to D.E. Schuler (YLFS), M. Crown and E. Van Eerden (formerly with the Pacific Forest Research Centre (PFRC)) for initiating and establishing the study. Gratitude is extended to D. White and G. Campbell, forest technicians (YLFS), and to C.R. Layton and D.R. Barwise, forest technicians (PFRC). Computer analyses of the data was performed by D. Beddows (PFRC).

## TABLE OF CONTENTS

ABSTRACT/RESUME . . . . . 5

INTRODUCTION . . . . . 8

DESCRIPTION OF STUDY AREAS . . . . . 8

METHODS

- Design, Block Layout and Site Preparation . . . . . 8
- Seed Collection and Sowing . . . . . 9
- Seedling Production and Planting . . . . . 10
- Assessment . . . . . 10

RESULTS

- Seeding . . . . . 12
  - Stocking . . . . . 12
  - Height . . . . . 12
- Planting . . . . . 12
  - Survival . . . . . 12
  - Height . . . . . 12
  - Injury and Mortality . . . . . 18

DISCUSSION

- Site Preparation . . . . . 18
- Season of Application . . . . . 21
- Planting and Seeding as Reforestation Options . . . . . 21

SUMMARY . . . . . 23

LITERATURE CITED . . . . . 23

APPENDIX . . . . . 25

## TABLES


1 Total precipitation and mean monthly temperature at the Watson Lake, Yukon Territory weather station . . . . . 9

2 Stock production and planting date . . . . . 11

3 Stock record of white spruce plug seedlings . . . . . 11

4 Fifth-year percent stocking of seeded trials. . . . . 14

5 Mean percent stocking levels by location and seeding method . . . . . 14

6 Mean percent stocking by ground treatment and seeding method . . . . . 15

7 Mean fifth-year height of seeded seedlings . . . . . 15

8 Mean seedling height by location and year of application . . . . 16

9 Fifth-year percent survival of planting trials . . . . . 16

10 Mean fifth-year height of planted seedlings. . . . . 17

11 Mean fifth-year height of planted stock by location and ground treatment. . . . . 17

## INTRODUCTION

Forest harvesting operations in the southeast Yukon have centered on floodplains of the Liard River drainage system for the past 35 to 40 years. Until recently, natural seeding from local sources has been entirely relied upon to regenerate logged areas.

In 1974, the Yukon Lands and Forest Service requested assistance in developing techniques for white spruce (*Picea glauca* (Moench) Voss) regeneration on recently logged cutovers. In 1975 a joint Yukon Lands and Forest Service (YLFS)-Pacific Forest Research Centre (PFRC) study was devised and implemented by M. Crown*, E. Van Eerden (PFRC)* and D.E. Schuler (YLFS)** to fulfill this request and to help develop local expertise in regeneration silviculture.

Reforestation options selected for testing include planting, broadcast seeding, spot seeding and seeding from natural sources. Treatments were applied on scarified and unscarified ground during two treatment periods (fall and spring) over two successive years (1975-1976; 1976-1977). Results after five growing seasons are reported.

## DESCRIPTION OF STUDY AREAS

Two areas, one on the Liard River (Lat. 60°08'N, Long. 128°58'W) and one on the Meister River (Lat. 60°20'N, Long. 129°35'W), were selected as test sites in June 1975. The areas fall within the B.24 section of the boreal forest described by Rowe (1972) and the Liard River ecoregion as classified by Oswald and Senyk (1977). The floodplains are at elevations of 180 m to 200 m and lie within the subarctic climatic zone with a frost-free growing period of about 60 days (Hirvonen 1968). The growing season temperature averaged 11.2°C for the period 1975 to 1980 inclusive, whereas the precipitation during the growing season averaged 262 mm over the same period (Table 1). The topography of both test areas is level.

Soils of the experimental areas are alluvial and classified as moderately well-drained (mildly acidic (average pH = 6.5)) regosols (Jeffrey 1964). Profiles are made up of alternating layers of coarse-textured sandy loams, silt loams and loamy sands. Base materials occur at 96 cm and consist of gravelly sands and fine to coarse sands with a few rocks.

## METHODS

### Design, Block Layout and Site Preparation

The experiment utilized a randomized complete block design incorporating a split-plot. Research blocks established in August-September 1975 were replicated three times on the Liard and four times on the Meister. In 1976 the blocks were replicated three additional times on each site. Each block measured 198 m x 93 m and had a total area of 1.8 ha. Experimental area for the entire study consists of six blocks on the Liard and seven on the Meister, totalling 23.9 ha.

One half of each block was strip scarified. Scarification at the Liard in 1975 was performed with a Caterpillar D6 equipped with a conventional blade angled 15 cm downward on one side whereas at the Meister a similarly equipped Komatsu D60A bulldozer was used. In 1976 scarification was accomplished at both sites using a Caterpillar D6 equipped with a brush blade which was not angled. The brush

* Currently on staff of B.C. Ministry of Forests, Duncan and Victoria, B.C., respectively.

** Staff Forester, Northern Affairs Program, Whitehorse, Yukon.

Table 1. Total precipitation and mean monthly temperature at the Watson Lake, Yukon Territory weather station.*

| | Precipitation (mm) | | | | | |
|---|---|---|---|---|---|---|
| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
| May | 4.3 | 41.9 | 87.6 | 22.3 | 23.9 | 32.7 |
| June | 70.1 | 77.7 | 52.9 | 37.8 | 92.7 | 47.8 |
| July | 127.2 | 28.4 | 98.8 | 87.8 | 52.8 | 65.3 |
| August | 56.1 | 58.9 | 20.6 | 48.5 | 8.9 | 39.9 |
| September | 32.2 | 38.4 | 45.9 | 42.0 | 42.7 | 77.6 |
| Total | 289.9 | 245.3 | 315.8 | 238.4 | 221.0 | 263.3 |

| | Temperature ($^{O}$C) | | | | | |
|---|---|---|---|---|---|---|
| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
| May | 7.4 | 6.7 | 6.4 | 7.1 | 5.8 | 8.2 |
| June | 11.7 | 11.1 | 12.5 | 13.2 | 11.5 | 14.7 |
| July | 15.3 | 13.1 | 14.1 | 14.9 | 16.2 | 14.6 |
| August | 12.1 | 13.1 | 15.5 | 12.9 | 15.0 | 11.3 |
| September | 9.1 | 8.4 | 7.3 | 7.9 | 8.9 | 5.8 |
| Avg. | 11.1 | 10.5 | 12.2 | 11.2 | 11.5 | 10.9 |

* Monthly Record of Meteorological Observations in Northern Canada. Environment Canada, UDC 551.506.1 (71) 551.521.12 (71) ISSN 0706-480X 1977-1980, and Monthly Record of Meteorological Observations in Canada, DOE 1973-1976.

blade was more efficient at splitting and removing stumps and production increased from 0.16 ha/h to 0.31 ha/h. Both blades produced strips of bare mineral soil devoid of vegetation and organic matter (Vandenberghe 1977).

The presence of stumps and accumulations of logging debris reduced the effective coverage of strip scarification to approximately 38% rather than the desired 50%. The scarified area in each block represents 0.346 ha, for a total of 4.49 ha for the study.

Following scarification, blocks were subdivided into ten equal plots measuring 19.8 m x 93 m (0.18 ha). Treatments were randomly allocated to the plots over fall-spring 1975-1976 (blocks 1 to 3 Liard, 1 to 4 Meister) and fall-spring 1976-1977 (blocks 4 to 6 Liard, 5 to 7 Meister).

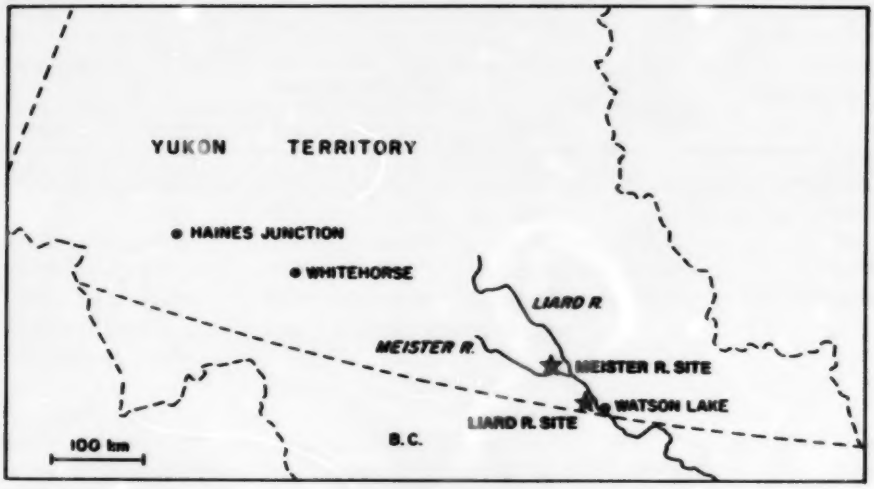
### Seed Collection and Sowing

Seed utilized in the study originated from two areas:

1. Haines Junction at Lat. 60$^{O}$45'N, Long. 137$^{O}$ 30'W at an elevation of 618 m.

2. Watson Lake at Lat. 60$^{O}$06'N, Long. 128$^{O}$50'W at an elevation of 701 m.

Cones were collected during August and September of 1973 and the seed was extracted in March 1974 at the Provincial Tree Nursery at Oliver, Alberta. The seed lots were inadvertently mixed. Ninety-five percent of the resultant mixture came from the Haines Junction source. Germination tests performed on an unstratified sample prior to sowing indicated a germination percentage of 78 (Vanderberghe 1977).




Location of test sites.

Spot and broadcast seeding were carried out in late August for fall applications and in June for spring applications in each of the two years. Ten plots per scarified and unscarified section were reserved in each block for the direct seeding treatments. These plots were each divided into two subplots—one was spot seeded and the other broadcast seeded. One plot in each section was reserved for natural seeding. Sample areas for natural, spot and broadcast seeding treatments were devoid of seedlings at the time of sowing.

Spot seeding was applied at a 1.22 m x 1.22 m spacing with six seeds sown per spot. In 1975-1976 seeds were covered lightly with mineral soil on the scarified areas and compacted. On unscarified areas, the duff layer at each spot was partly cleared and the seeds were covered lightly with organic material and compacted. In 1976-1977 all seeds were placed on the surface and pressed into the ground by foot.

All broadcast seeding treatments were applied using a Cyclone model 10 seeder calibrated to distribute 2.24 kg of seed per hectare.

### Seedling Production and Planting

Stock for the planting trials was raised at PFRC in BC/CFS styroblock 2A containers. Summaries of the production and planting schedules and morphological characteristics of the stock are presented in Tables 2 and 3.

Within the scarified section of each block, one plot was reserved for spring planting and one was reserved for fall planting. Three microsites were identified. Slope microsites consisted of the edges of the scarified strips; flat microsites were those areas compressed by the tractor pads; and microsites referred to as humps were located on the mounded area between the tracks of the tractor (i.e., between the flat microsites). Two lines of 50 seedlings were planted on each microsite during spring and fall planting.

Within unscarified areas, two lines of seedlings were planted on separate plots during spring and fall planting periods, respectively.

### Assessment

The trials were assessed after one, three and five growing seasons. Recorded observations include the condition of each seedling (alive, dead or injured) and total height.

Natural and broadcast seeding treatments were evaluated by selecting fifty 0.5 $m^2$ areas within each subplot. For spot seeding, 50 randomly selected seeded

Table 2. Stock Production and Planting Date.

| Stock Care and Planting | 1975-1976 | 1976-1977 |
|---|---|---|
| Seed Sown at PFRC | March 26, 1975 | January 15, 1976 |
| PFRC Greenhouse | March 26 to June 26 | January 15 to May 24 |
| PFRC Shadehouse | June 27 to July 6 | May 25 to July 18 |
| In Transit | July 7 to July 11 | July 19 to July 22 |
| YLFS Plastic House, Watson Lake | July 12 | July 23 |
| Fall Planting: Liard | September 2, 1975 | September 8, 1976 |
| Meister | September 10, 1975 | September 10 and 11, 1976 |
| Spring Planting: Liard | June 2 and 7, 1976 | June 27, 1977 |
| Meister | June 3 and 4, 1976 | June 24, 1977 |

Table 3. Stock record of white spruce plug seedlings planted 1975 to 1977.

| | Height | Dry Weight (g) | | | Root Collar Diameter (mm) |
|---|---|---|---|---|---|
| | | Top | Root | Total | |
| **1975-1976** | | | | | |
| September 4, 1975 | 9.9 | 0.50 | 0.27 | 0.77 | 1.9 |
| June 14, 1976 | 13.4 | 0.87 | 0.35 | 1.22 | 2.6 |
| **1976-1977** | | | | | |
| September 20, 1976 | 17.6 | 1.18 | 0.78 | 1.96 | 2.3 |
| *No spring sample* | ..... | ..... | ..... | ..... | ..... |

spots were sampled from each subplot. The number of germinants and resultant seedlings were tallied with height measurements recorded in the third and fifth year after establishment.

Percent survival data were adjusted with an arcsine transformation and, together with height data, subjected to analysis of variance.

## RESULTS

### Seeding

#### Stocking

Table 4 presents a summary of fifth-year stocking of white spruce on seeded areas of the study.

Significant differences in stocking levels were observed between locations, ground treatments, and among seeding methods (Figs. 1, 2, 3) after five years.

Average stocking achieved on scarified ground was approximately eight times that on unscarified sites. Liard stocking was double that of the Meister (Table 5), while seeding methods averaged a stocking ratio of 1.9:1.4:1 for broadcast, natural and spot seeding, respectively. Relationships established between locations and ground treatments at the beginning of the study remained relatively consistent throughout. Stocking achieved by natural seeding surpassed that of spot seeding by the third year. However, broadcast seeding continued to be the significantly superior treatment.

No significant differences ($P \leq .05$) were observed between spring and fall (average stocking 26.5% and 26.8%, respectively) or between the first-year and second-year (average stocking 27.8% and 25.5%, respectively) applications.

By the standards of Candy (1951) only moderate levels of stocking were achieved. Scarification resulted in an eightfold increase in stocking level on spot and broadcast seeded areas and a fivefold increase in stocking level on naturally seeded areas (Table 6). Stocking level was more sensitive to location than to method of application. Broadcast seeding significantly outperformed other seeding methods five years after application on scarified ground.

#### Height

Table 7 presents a summary of the fifth-year height of direct seeded and natural seedlings.

Season, year of application and seeding method influenced height development of seeded seedlings (Figs. 4, 5, 6). Seedlings established in the fall averaged nearly twice the height of spring-sown trees. Seedlings established in the second year of application were significantly taller than those sown in the first year. There were no significant differences between trees sown naturally and trees sown by broadcast seeding but those sown by spot seeding were significantly shorter by the fifth year.

Seedlings sown in 1976-1977 were consistently taller than those sown in 1975-1976 (Fig. 5). The only interaction involving year of application which produced significant differences in height development was with location. Data presented in Table 8 suggest that most of the variation may be attributable to poor height development of seedlings sown in 1975-1976 on the Meister. The first growing season of these sowings (1976) was drier and cooler than that of the second seeding application (1977) (Table 1). Germination and establishment of seedlings may have been adversely affected in the first year on the Meister which is a much more open and exposed site than the Liard.

### Planting

#### Survival

Survival of planted seedlings was generally high (Table 9).

Throughout the study, spring-planted seedlings achieved higher survival rates than fall-planted seedlings (Fig. 7). Seedlings planted on unscarified ground attained significantly lower survival than those planted on scarified ground (Fig. 8). This result suggests a longer term value of scarification. Survival on unscarified ground was superior in the first year, but since has declined steadily whereas survival on scarified sites stabilized in the first season and changed little over the next four. Significant variation in survival was not detected between locations or years of planting.

#### Height

Table 10 presents a summary of fifth-year height of planted seedlings.

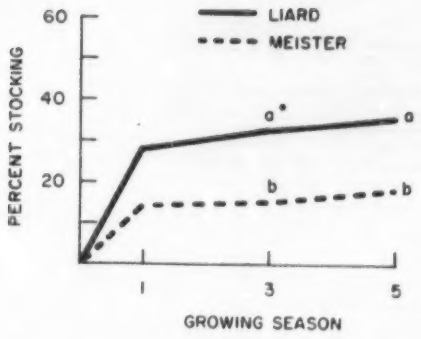



Fig. 1. Average stocking (%) by location over five growing seasons.

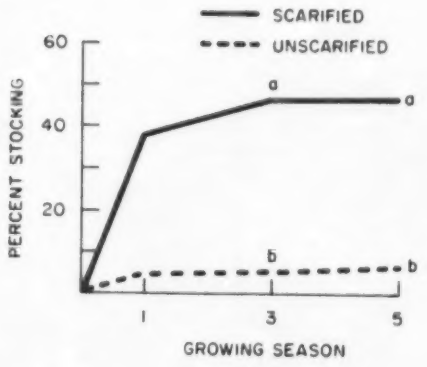



Fig. 2. Average stocking (%) by ground treatment over five growing seasons.

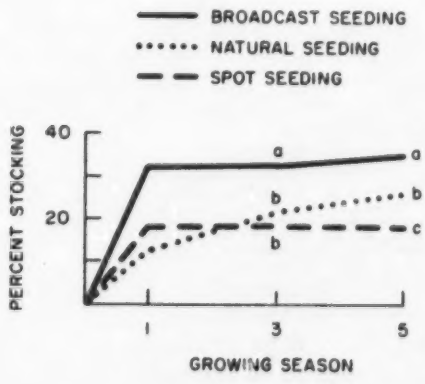



Fig. 3. Average stocking (%) by seeding method over five growing seasons.

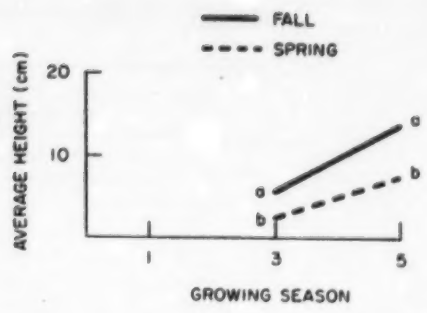



Fig. 4. Average height (cm) of seeded stock by season of application over five growing seasons.

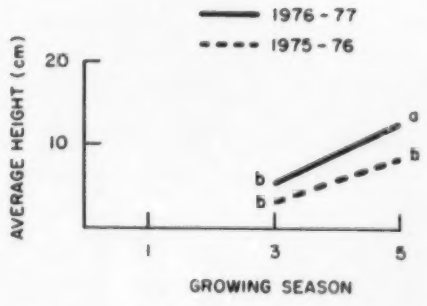



Fig. 5. Average height of seeded stock by year of application over five growing seasons.

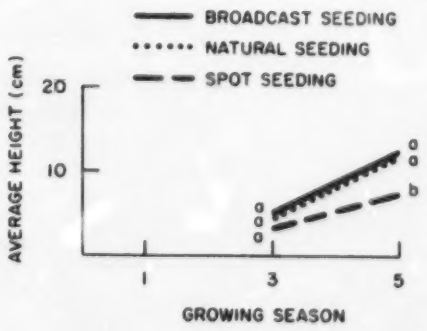



Fig. 6. Average height (cm) of seeded stock by method of application over five growing seasons.

* Means within each growing season followed by the same letter are not significantly different ($P \leq 0.05$).

Table 4. Fifth-year percent stocking of seeding trials.

| | | Seeding Method | | |
|---|---|---|---|---|
| | | Natural | Spot | Broadcast |
| Liard | | | | |
| Scarified: | | | | |
| Fall | – 1* | 64 | 41 | 67 |
| | – 2 | 59 | 43 | 67 |
| Spring | – 1 | 64 | 41 | 78 |
| | – 2 | 59 | 45 | 76 |
| Unscarified: | | | | |
| Fall | – 1 | 14 | 5 | 9 |
| | – 2 | 31 | 11 | 25 |
| Spring | – 1 | 14 | 13 | 17 |
| | – 2 | 0 | 0 | 0 |
| Meister | | | | |
| Scarified: | | | | |
| Fall | – 1 | 36 | 22 | 51 |
| | – 2 | 19 | 18 | 45 |
| Spring | – 1 | 36 | 25 | 62 |
| | – 2 | 19 | 25 | 59 |
| Unscarified: | | | | |
| Fall | – 1 | 1 | 1 | 2 |
| | – 2 | 4 | 2 | 5 |
| Spring | – 1 | 1 | 1 | 3 |
| | – 2 | 0 | 0 | 0 |

* 1 indicates 1975-1976.
2 indicates 1976-1977.

Table 5. Mean percent stocking levels by location and seeding method.*

| | Seeding Method | | |
|---|---|---|---|
| | Natural | Spot | Broadcast |
| Liard | 38.2a** | 25.0b | 42.5a |
| Meister | 14.3c | 11.8c | 28.1b |

* Ground treatment, season and year combined.

** Numbers followed by the same letter are not significantly different ($P \leq .05$).

Table 6. Mean percent stocking by ground treatment and seeding method.*

| | Seeding Method | | |
|---|---|---|---|
| | Natural | Spot | Broadcast |
| Scarified | 44.4b** | 32.6c | 63.0a |
| Unscarified | 8.2d | 4.2d | 7.6d |

* Location, season and year combined.

** Numbers followed by the same letter are not significantly different (P ≤ .05).

Table 7. Mean fifth-year height (cm) of seeded seedlings.

| | Seeding Method | | |
|---|---|---|---|
| | Natural | Spot | Broadcast |
| Liard | | | |
| Scarified: | | | |
| Fall – 1* | 9 | 10 | 10 |
| – 2 | 14 | 15 | 16 |
| Spring – 1 | 9 | 6 | 12 |
| – 2 | 14 | 11 | 17 |
| Unscarified: | | | |
| Fall – 1 | 14 | 7 | 14 |
| – 2 | 22 | 13 | 23 |
| Spring – 1 | 1 | 4 | 16 |
| – 2 | 0 | 0 | 0 |
| Meister | | | |
| Scarified: | | | |
| Fall – 1 | 6 | 8 | 9 |
| – 2 | 12 | 12 | 13 |
| Spring – 1 | 6 | 9 | 11 |
| – 2 | 12 | 10 | 11 |
| Unscarified: | | | |
| Fall – 1 | 1 | 3 | 8 |
| – 2 | 45 | 9 | 31 |
| Spring – 1 | 1 | 5 | 6 |
| – 2 | 0 | 0 | 0 |

* 1 indicates 1975-1976.
2 indicates 1976-1977.

Table 8. Mean seedling height (cm) by location and year of application.*

| | Year of Application | |
|---|---|---|
| | 1975-1976 | 1976-1977 |
| Liard | 10.6a** | 12.1a |
| Meister | 6.1b | 12.0a |

* Season, ground treatment and seeding method combined.

** Numbers followed by the same letter are not significantly different ($P \leq .05$).

Table 9. Fifth-year percent survival of planting trials.

| | | Ground Treatment | | | |
|---|---|---|---|---|---|
| | | | Scarified | | |
| | | Unscarified | Flat | Slope | Hump |
| Liard | | | | | |
| Fall | – 1* | 87 | 84 | 87 | 91 |
| | – 2 | 91 | 84 | 88 | 82 |
| Spring | – 1 | 79 | 72 | 77 | 75 |
| | – 2 | 90 | 96 | 94 | 97 |
| Meister | | | | | |
| Fall | – 1 | 73 | 94 | 91 | 95 |
| | – 2 | 66 | 91 | 92 | 91 |
| Spring | – 1 | 79 | 91 | 92 | 93 |
| | – 2 | 88 | 96 | 93 | 95 |

* 1 indicates 1975-1976.
2 indicates 1976-1977.

Table 10. Mean fifth-year height (cm) of planted seedlings.

| | | Ground Treatment | | | |
|---|---|---|---|---|---|
| | | | Scarified | | |
| | | Unscarified | Flat | Slope | Hump |
| Liard | | | | | |
| Fall | – 1* | 30.4 | 44.5 | 50.8 | 52.4 |
| | – 2 | 35.2 | 42.8 | 46.6 | 47.2 |
| Spring | – 1 | 39.7 | 38.3 | 40.9 | 45.6 |
| | – 2 | 35.9 | 43.7 | 44.5 | 43.1 |
| Meister | | | | | |
| Fall | – 1 | 25.5 | 38.4 | 46.4 | 47.2 |
| | – 2 | 26.2 | 35.5 | 39.8 | 43.9 |
| Spring | – 1 | 34.6 | 40.0 | 43.8 | 43.8 |
| | – 2 | 31.3 | 39.8 | 40.9 | 40.1 |

* 1 indicates 1975-1976.
2 indicates 1976-1977.

Table 11. Mean fifth-year height (cm) of planted stock by location and ground treatment. *

| | Ground Treatment | | | |
|---|---|---|---|---|
| | | Scarified | | |
| | Unscarified | Flat | Slope | Hump |
| Liard | 37.5c** | 42.3b | 45.7a | 45.8a |
| Meister | 29.4d | 38.4c | 42.7ab | 43.7ab |

* Season and year combined.

** Numbers followed by the same letter are not significantly different ($P \leq .05$).

Significant variation in height growth was observed between location, season and year of establishment and among ground treatments (Figs. 9, 10, 11, 12). The largest differences resulted from the influences of microsite and ground treatment. Data in Table 11 illustrate the interaction of location and ground treatment.

Fall planting tended to outperform spring planting. Trees established in the second year were significantly taller after one growing season than those planted in year one, possibly due to an initial height advantage at planting. However, this circumstance reversed itself by the fifth year (Fig. 10).

### Injury and Mortality

Current injury to surviving stock and mortality over the last two seasons of the study by location are summarized in the Appendix, Tables I and II.

Frost damage, smothering from vegetative competition and insects (principally Cooley's spruce gall aphid (*Chermes cooleyi*)) were the major sources of current injury to planted stock at the Liard (Table I). At the Meister, drought injury was more prevalent than insect damage, and needle rust (*Chrysomyxa ledicola*) was common on seedlings planted in the second year (Table I). Frost damage was also extensive at both sites and was generally attributable to late frosts killing newly flushed growth in the spring. Frost heaving of the root plugs was common on very exposed areas as well. Throughout the areas, scattered instances of seedling erosion due to water action, browsing by wildlife and mechanical damage (usually breakage) were recorded.

At the Liard site drought was a major cause of mortality of trees planted in year one, whereas mortality of trees planted in year two was mostly caused by smothering from vegetation (Table II). This served to illustrate the diversity in environment which was found within relatively short distances on what would appear to be a homogeneous site.

At the Meister site, mortality was mainly attributable to smothering from competing vegetation, particularly grass. Secondary factors included drought and frost (Table II).

There were a number of edaphic and biotic factors hampering planted seedlings during the critical establishment years on these sites, but final mortality appeared to relate to those factors which deprived the trees of moisture or the living space necessary to sustain growth.

## DISCUSSION

### Site Preparation

Scarification significantly improved survival and height growth of planted or seeded trees. Exposed mineral soil provides a suitable seedbed for germination of white spruce seed (Dobbs 1972; Place 1955; Rowe 1955; Stiell 1976; Waldron 1966; Zasada 1969, 1972). Desirable seedbed qualities are moisture-retaining capability, an absence of vegetative competition and a ready source of soluble nutrients (Arnott 1973; Griffin and Carr 1973; Richardson 1973). Unscarified ground provides few, if any, of these requirements. Humus or duff layers are poor moisture-retaining media when exposed following logging. Eis (1965) reported that raw organic matter layers on cutovers near Prince George, British Columbia, reached the wilting point within a few days following rain. Alluvial floodplain sites in the study area are productive and reinvasion of annual and perennial forbs and shrubs follows within two to three seasons of harvesting unless old root stocks and residuals are removed.

Thick organic layers (mosses and humus) which tend to develop under spruce stands generally remain intact following winter logging in the Yukon. This accounts for delayed thawing of soil in the spring and low soil temperatures (Viereck 1970) which may reduce the rate of decomposition of overlying organic matter and thus the rate of nutrient cycling (Zasada *et al.* 1977).

Blade scarification, as applied in this study, created a swath of bare mineral soil. As a vegetation control measure this form of preparation appeared successful. Mineral soil surfaces exposed by scarification were still in evidence five years later on most blocks. Reinvasion of vegetation, particularly by grass, appeared to be confined to areas which were in close proximity to residual vegetation. The observation that stocking levels on scarified areas are increasing more rapidly than on unscarified areas after five seasons indicates that the prepared seedbeds are still more receptive.

Survival and growth rate of planted seedlings were superior on scarified ground. Zasada and Grigal (1978), in a study of natural regeneration with blade

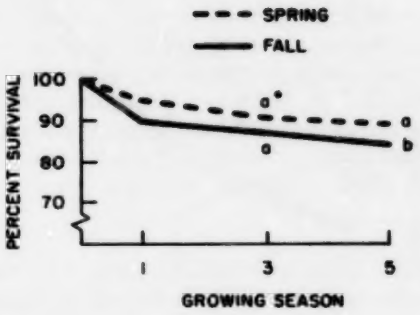



Fig. 7. Survival (%) of planted stock by season of planting over five growing seasons.

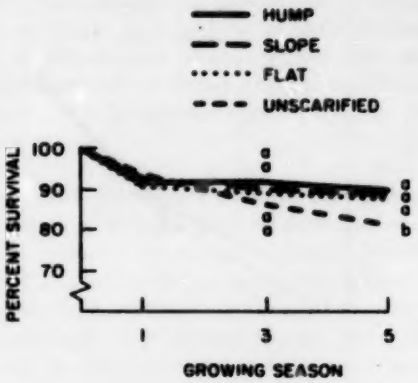



Fig. 8. Survival of planted stock by ground treatment over five growing seasons.

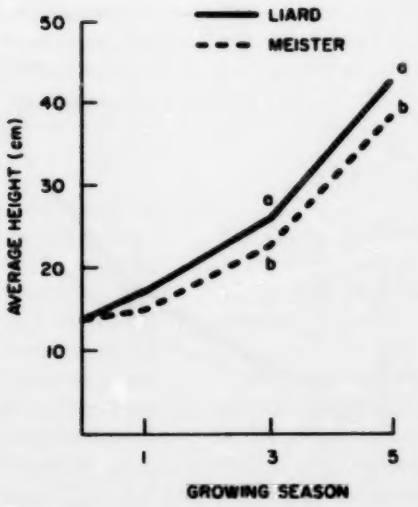



Fig. 9. Average height of planted stock by location over five growing seasons.

* Means within each growing season followed by the same letter are not significantly different ($P \leq .05$).

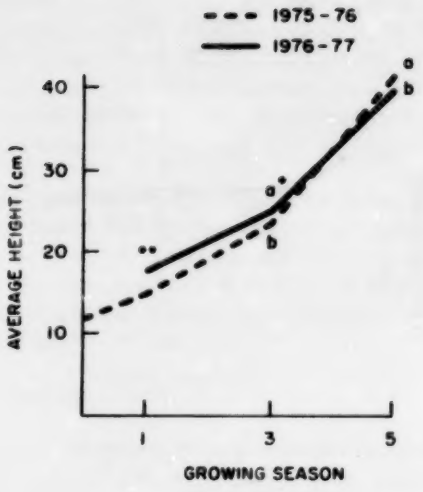



Fig. 10. Average height of planted stock by year of planting over five growing seasons.

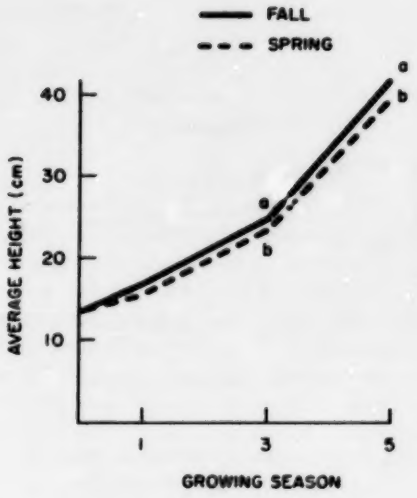



Fig. 11. Average height of planted stock by season of planting over five growing seasons.

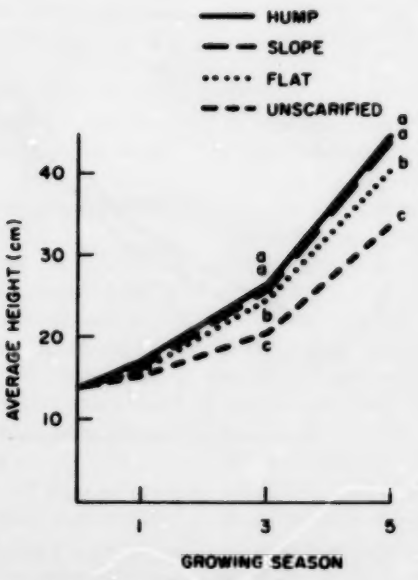



Fig. 12. Average height of planted stock by growing treatment over five growing seasons.

* Means within each growing season followed by the same letter are not significantly different ($P \leq 0.05$).

** Initial height data not available for year 2 planting.

scarification in white spruce types in Alaska, found that much higher levels of stocking and larger seedlings were produced on scalped areas than on undisturbed areas. They reported that site treatment had little effect on natural levels of exchangeable potassium and total nitrogen in the mineral soil. On the Liard and Meister, stocking levels achieved with seeding were dramatically increased on scarified surfaces and height growth was comparable to that on unscarified sites. It may be inferred that blade scarification did not lower site quality on the areas examined.

Some soil compaction probably occurred on these sites. Height of planted seedlings was significantly less on flat microsites compared to other scarified microsites (Table 11). Compaction from the weight of the bulldozer may have reduced aeration and water penetration initially with the result that roots of seedlings located on these microsites may have had difficulty penetrating and establishing a root-soil interface at the time of planting. As well, field observations indicated that these lower sites may have been prone to localized flooding and frost pocketing. Conditions for growth on humped or elevated microsites were likely better. Soderstrom *et al.* (1978) stated that heaped microsites had elevated, exposed, loosely compacted soils affording good aeration and water drainage, unrestricted root penetration, and freedom for vegetative competition. On the Liard and Meister, planting on elevated microsites was sufficient to eliminate significant height variation between locations (Table 11).

River floodplains are situated at lower elevations than surrounding terrain and are therefore susceptible to occasional flooding and/or frost pocketing. Blade scarification, which tends to create troughs, can exacerbate these problems if it is not properly applied. Care should be taken to orient it in the direction of prevailing winds and towards lower elevations to allow for proper air and surface water drainage. Dips and rolls should be avoided to prevent creation of local frost pockets and water catchments.

### Season of Application

Season of application effects on seeding success were inconclusive. Better stocking was achieved with spring applications yet fall-seeded seedlings were significantly taller. Stiell (1976) reported that some investigators preferred spring applications which allow for a period of natural cold stratification and take advantage of favorable moisture conditions and peak germination periods. Hellum (1974) demonstrated that, for white spruce in Alberta, winter-spring applications clearly produced better stocking than summer or fall sowings. Sutton (1969) felt that ultimate performance of seeded seedlings may be influenced as much by seedbed conditions as by the sowing season.

Similar seasonal effects were observed with planted seedlings. Spring plantings gave consistently better survival than fall planting but produced smaller seedlings. Gains in survival of spring over fall planting amounted to 4.8% whereas differences in average total height after five growing seasons amounted to 1.8 cm, or 4.3%, in favor of fall-planted seedlings. These results, although statistically significant, may not constitute large differences in real terms. The physiological and morphological condition of stock at planting play important roles in success of operations (Ackerman and Johnson 1962) as do microsite conditions resulting from site preparation (McMinn 1977). Decisions concerning time of planting may have to be made on an annual basis on floodplain sites in the Liard drainage. Spring planting in the second year of the study was delayed by lingering snow and flooding until late June with the result that stock had flushed prior to planting. Planting stock in this condition is undesirable and leads to reduced survival and height growth. Under such conditions cold-stored stock should have been used.

### Planting and Seeding As Reforestation Options

The results of this study clearly show that seeding of any type on unscarified ground and spot seeding on scarified areas are not satisfactory reforestation options.

Figure 3 shows that stocking levels on naturally seeded areas are still on the increase after five seasons as are those on broadcast seeded areas (which indicates that broadcast and spot seeding treatments are likely being supplemented with naturally established seedlings). To date, broadcast seeding on scarified ground produced the best results (63% stocking). Information does not currently exist to suggest what levels of stocking could be expected over time on these floodplain sites. Stand densities of 8 771 and 12 587 stems per hectare have been produced by natural and broadcast treatments, respectively, over five seasons on scarified ground based on present stocking of the 0.5 $m^2$ sample plots.

Location and ground treatment were more important sources of variation of seeding stocking levels than was the seeding method (Tables 5, 6).

Planted seedlings were established at a density of 1660 trees per hectare. Densities after five years are 1477 stems per hectare (89% survival) and 1460 stems per hectare (88% survival) on scarified and unscarified ground, respectively. These densities are well above provincial requirements for spruce sawlog stands in Alberta (610 trees per hectare) (Bella and DeFraceschi 1978).

Stiell (1976) reported that the major advantages of seeding over planting are monetary savings (up to 38% on a per hectare basis) and the possibility of retreatment of areas at a reasonable cost should initial seeding fail. Disadvantages include the enormous quantities of seed required and lack of control over ecological factors controlling germination and initial establishment. Due to the latter disadvantage, investigators have stressed the unreliability of seeding to produce well stocked stands and the erratic results achieved in earlier attempts (Richardson 1973; Stiell 1976; Waldron 1974). Hellum (1974) suggested that direct seeding failures may be related to misapplication of techniques and indicated that development and/or refinement of scarification, seed quantities applied and season of application might overcome many of the difficulties.

Although planting is considered to be a more reliable reforestation technique (Dobbs 1972) direct and/or natural seeding should not be discounted. Facilities to produce container or bareroot seedlings on an operational basis do not currently exist in the Yukon and access to the majority of cutblocks is difficult. The costs of start-up and maintenance of a reforestation system based on seedling production and planting and the fact that seedlings and attendant crews would have to be ferried into sites by boat or helicopter may make seeding options justifiable from an economic standpoint.

Biologically, there are two points which should be given consideration:

1. Scarification on plots designated for planting and natural seeding was applied in an identical manner. The relative position of the plots in the cutblocks were the same. Therefore, it is a valid assumption that natural seeding occurred on scarified plots which were planted at the same rate as on plots which were left to seed naturally. It is conceivable then that planted seedlings at a fifth-year density of 1477 stems per hectare, as in this study, would make up only 17% of the spruce which may actually be on the site (assuming a natural density at year five of 8771 stems per hectare on scarified ground). What the proportions of naturally seeded trees and planted trees would be at rotation age is unknown, but it is possible that naturally established trees would make up a greater portion of the final stand than planted trees if the plantations were left untended.

2. The average height of seeded seedlings on scarified ground (fall and spring sowings combined) was 10.9 cm. Trees planted in the fall of 1975 averaged 9.9 cm (Table 3) which represented the average height of stock at the end of nursery production at the Pacific Forest Research Centre. This result indicates that the height advantage of planted stock used in this study (which was produced and planted in the same year) represented, at best, five years of growth. The question remains as to whether this will be significant over the rotation period.

Given these latter observations and that reforestation by plantation may not be feasible at present, it is suggested that seeding techniques may be appropriate for regeneration of white spruce on floodplain sites in the Yukon. Provided that scarification to expose mineral soil is performed at time of harvesting, a simultaneous application of broadcast seeding may prove sufficient to establish white spruce successfully on cutbacks. A regeneration survey for germinants should be performed at the end of the summer following seeding. If stocking is inadequate, the areas should be reseeded the following winter as the scarified seedbeds should still be receptive the spring of the second year. Stocking from broadcast seeding increased just 3% over five years (Fig. 3) so a regeneration survey after the first season should indicate success or failure. Seeding treatments may be enhanced by regulating the harvest to take advantage of natural seed sources.

Further investigation of alluvial floodplain ecology in the Yukon is required to allow development of improved regeneration techniques for white spruce.

## SUMMARY

1. Direct seeding and natural seeding on unscarified ground were unsuccessful.

2. Broadcast seeding on scarified ground achieved moderate success.

3. Spring or fall applications did not affect stocking or height development of seeded seedlings.

4. Blade scarification was effective in controlling vegetation and exposing mineral soil for initial germination.

5. Spring planting gave the best survival rates, but fall planting produced taller seedlings.

6. Best survival and height development for planted seedlings was obtained on elevated microsites on scarified ground.

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# APPENDIX

Table I. Year 3 to Year 5 Mortality by Injury—Liard (L) and Meister (M).

| | Total Mortality | | Injury | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Frost Damage | | Erosion of Seedling | | Smothering | | Mechanical Damage | | Browsing | | Drought | | Insects | | Disease | | Unknown | |
| | L | M | L | M | L | M | L | M | L | M | L | M | L | M | L | M | L | M | L | M |
| 1975-1976: | | | | | | | | | | | | | | | | | | | | |
| Fall – Unscarified | 12 | 29 | 0 | 6 | 7 | 1 | 0 | 18 | 0 | 0 | 1 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 1 | 2 |
| – Scarified – Flat | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| – Slope | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| – Hump | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spring – Unscarified | 7 | 15 | 2 | 4 | 0 | 0 | 2 | 7 | 0 | 1 | 0 | 0 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| – Scarified – Flat | 7 | 3 | 3 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| – Slope | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| – Hump | 2 | 5 | 0 | 0 | 0 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1976-1977: | | | | | | | | | | | | | | | | | | | | |
| Fall – Unscarified | 1 | 15 | 0 | 3 | 0 | 0 | 1 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| – Scarified – Flat | 4 | 4 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| – Slope | 2 | 3 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| – Hump | 5 | 2 | 0 | 0 | 1 | 0 | 3 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Spring – Unscarified | 6 | 15 | 0 | 1 | 0 | 0 | 5 | 10 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 0 |
| – Scarified – Flat | 2 | 4 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| – Slope | 6 | 4 | 0 | 0 | 2 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| – Hump | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table II. Injuries Affecting Live Trees at Fifth-Year Assessment—Liard (L) and Meister (M).

| | Total Trees Alive | | Injury | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Frost Damage | | Erosion of Seedling | | Smothering | | Mechanical Damage | | Browsing | | Drought | | Insects | | Disease | | Unknown | |
| | L | M | L | M | L | M | L | M | L | M | L | M | L | M | L | M | L | M | L | M |
| **1975-1976:** | | | | | | | | | | | | | | | | | | | | |
| Fall – Unscarified | 262 | 284 | 1 | 16 | 0 | 1 | 9 | 19 | 1 | 4 | 2 | 0 | 0 | 64 | 57 | 4 | 0 | 2 | 20 | 2 |
| – Scarified – Flat | 251 | 373 | 3 | 10 | 0 | 0 | 6 | 9 | 1 | 4 | 2 | 0 | 5 | 50 | 21 | 3 | 0 | 1 | 5 | 0 |
| – Slope | 260 | 365 | 2 | 10 | 1 | 7 | 0 | 12 | 0 | 3 | 1 | 0 | 7 | 37 | 11 | 1 | 0 | 0 | 3 | 0 |
| – Hump | 274 | 378 | 2 | 7 | 1 | 3 | 0 | 5 | 0 | 6 | 0 | 0 | 1 | 56 | 17 | 5 | 0 | 0 | 8 | 0 |
| Spring – Unscarified | 272 | 262 | 34 | 19 | 0 | 0 | 2 | 23 | 0 | 7 | 0 | 0 | 0 | 75 | 19 | 0 | 0 | 5 | 0 | 0 |
| – Scarified – Flat | 252 | 315 | 9 | 15 | 1 | 0 | 1 | 20 | 0 | 1 | 0 | 0 | 2 | 49 | 21 | 6 | 2 | 2 | 20 | 0 |
| – Slope | 263 | 369 | 18 | 13 | 0 | 0 | 4 | 15 | 0 | 6 | 0 | 0 | 0 | 25 | 8 | 13 | 0 | 4 | 13 | 0 |
| – Hump | 245 | 364 | 1 | 11 | 0 | 1 | 1 | 21 | 0 | 4 | 1 | 0 | 0 | 35 | 8 | 6 | 1 | 1 | 11 | 0 |
| **1976-1977:** | | | | | | | | | | | | | | | | | | | | |
| Fall – Unscarified | 236 | 235 | 16 | 31 | 0 | 0 | 0 | 14 | 0 | 11 | 0 | 2 | 0 | 19 | 11 | 5 | 1 | 36 | 2 | 0 |
| – Scarified – Flat | 214 | 274 | 13 | 5 | 0 | 0 | 7 | 9 | 0 | 2 | 2 | 0 | 0 | 100 | 18 | 1 | 0 | 1 | 0 | 0 |
| – Slope | 228 | 275 | 12 | 2 | 0 | 0 | 14 | 13 | 1 | 4 | 0 | 0 | 2 | 83 | 24 | 0 | 1 | 0 | 0 | 0 |
| – Hump | 225 | 278 | 12 | 1 | 0 | 0 | 10 | 22 | 0 | 0 | 0 | 0 | 0 | 74 | 22 | 0 | 6 | 4 | 1 | 0 |
| Spring – Unscarified | 268 | 263 | 0 | 18 | 0 | 0 | 7 | 25 | 0 | 8 | 0 | 0 | 0 | 46 | 47 | 2 | 0 | 64 | 2 | 0 |
| – Scarified – Flat | 288 | 289 | 1 | 10 | 3 | 0 | 2[illegible] | 22 | 1 | 3 | 0 | 1 | 0 | 94 | 46 | 1 | 0 | 35 | 0 | 0 |
| – Slope | 282 | 280 | 17 | 7 | 0 | 0 | 14 | 24 | 0 | 1 | 1 | 0 | 0 | 78 | 20 | 4 | 2 | 34 | 0 | 0 |
| – Hump | 292 | 285 | 2 | 9 | 1 | 0 | 25 | 4 | 0 | 3 | 0 | 0 | 0 | 96 | 68 | 3 | 0 | 41 | 0 | 0 |